Money Growth Volatility and the Demand for Money in Germany: Friedman's Volatility Hypothesis Revisited

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Abstract

Recently, the Bundesbank claimed that monetary targeting has become considerably more difficult by the increased volatility of short–term money growth. The present paper investigates the impact of German money growth volatility on income velocity and money demand in view of Friedman's money growth volatility hypothesis. Granger–causality tests provide some evidence for a velocity/volatility linkage. However, the estimation of volatility–augmented money demand functions reveals that — in contrast to Friedman's hypothesis — increased money growth volatility *lowered* the demand for money.

Keywords: Money growth volatility, demand for money, ARCH models.

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1 Introduction

The so–called "monetarist experiment" of the Federal Reserve — started in October, 1979 — ended rather ingloriously in the 1982 recession with a serious decline in income velocity. As the velocity decline reduced nominal GNP growth and thus may have helped cause the fall in real GNP, U.S. monetary policy came under heavy criticism. Moreover, the decline in velocity questioned monetarist beliefs concerning a predictable link between money and nominal income, i.e. a stable demand for money. Actually, this episode was sometimes interpreted as the "demise of monetarism", see e.g. McCallum (1989). On the other hand, Mascaro and Meltzer (1983) and particularly Milton Friedman (1984) argued that the observed velocity decline was solely caused by the increased *volatility* of money growth following the announced change in Federal Reserve operating procedures. More precisely, Friedman's "volatility hypothesis" states that increased volatility of money growth raises the degree of perceived uncertainty and thereby increases the demand for money (and, thus, reduces the income velocity). Hence, following Friedman, the failure of U.S. monetary policy in the early 1980s even strengthens, rather than weakens, the case for the monetarist proposition of a constant growth rule of money supply.

In Germany, monetary targeting has proved to be successful and has remained the Bundesbank's basic policy regime since the mid–seventies.[1] However, uncertainty about the development of money growth grew substantially due to the turbulences caused by the German monetary union in 1990, the Maastricht treaty in 1991, the EMS crisis in 1992, and various other "disruptive influences" that apparently undermine the Bundesbank's attempts to sustain a predictable growth of money supply. Recently, the

[1] For a comprehensive presentation of the Bundesbank's monetary policy, see e.g. Neumann and von Hagen (1993).

Bundesbank had to admit that "monetary policy [...] was made considerably more difficult by the increased volatility of short–term monetary growth", see Bundesbank (1995a, p.68). Whether money growth volatility is due to policy failures (as presumably in the U.S. from 1979 to 1982) or by more exogenous events (as presumably in Germany in the 1990s), Friedman's volatility hypothesis predicts a rise in money demand in any case.

However, recent empirical studies do not provide much support for this idea. For the United States, Mehra (1989) and Brocato and Smith (1989) demonstrated via Granger–causality tests that the volatility of M1 money supply is of little help in predicting income velocity. In the same vein, Thornton (1995) shows in a multi–country study that the M1–volatility/velocity linkage is weak for many industrial countries. Interestingly, Thornton's results suggest that money growth volatility has an impact on velocity especially when the central bank puts emphasis on monetary targeting. In fact, using data from 1976 up to 1989, Thornton (1995) shows that German M1 money growth volatility Granger–causes income velocity, while no causality can be found from 1960 until 1975, i.e. before monetary targeting has been established by the Bundesbank.

This paper reexamines the relation between money growth volatility, income velocity, and the demand for money for the unified Germany. In section 2, we follow the approach of former studies and use the Granger–causality method to test the general hypothesis that money supply volatility, conventionally proxied by a moving standard deviation of money growth, causes income velocity to change.

However, since changes in velocity may result from a number of factors acting simultaneously, conclusions solely based on bivariate causality tests could be misleading. In section 3, we therefore reexamine the role of money growth volatility within the more general framework of a money demand function that controls the influence of other relevant factors like interest rates and prices. Moreover, we estimate the ARCH component of a univariate money growth forecast equation and test for the significance of the derived *conditional* standard deviation which can be interpreted as *expected* money growth volatility. The rationale behind this approach is that expected volatility should be a more convincing proxy for *perceived* uncertainty than the conventional standard deviation used so far. Section 4 provides a summary and concluding remarks.

2 Does Money Growth Volatility Cause Income Velocity?

Hall and Noble (1987) were the first to investigate Friedman's volatility hypothesis empirically. In accordance with Friedman they showed via Granger–causality tests that U.S. money growth volatility causes income velocity to change. Using seasonally adjusted quarterly data they estimated an equation of the following form:

$$\Delta V_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta V_{t-i} + \sum_{j=1}^{q} \beta_j S_{t-j} + \varepsilon_t \tag{1}$$

where V is the log level of income velocity (for M1), S is the level of M1 money growth volatility, calculated as an eight–quarter moving standard deviation of quarterly money growth rates, and ε is a white noise error term.

In this section we adopt this approach and perform Granger–tests for German money growth volatility and income velocity. However, in view of the Bundesbank's monetary policy practice we focus on the volatility/velocity linkage of the monetary target aggregate M3. Moreover, we decided to base the definition of the volatility proxy on annual, rather than quarterly, growth rates because monetary targets are always announced with respect to annual growth rates. The degree of money growth volatility, conventionally calculated as a moving two–year standard deviation of money growth, strongly depends on this choice. Figure 1 illustrates that the increased volatility of M3 growth rates claimed by the Bundesbank is only revealed in case of annual growth rates.[2]

As the Bundesbank started monetary targeting in the mid–seventies, our sample begins in 1976(1) and ends in 1995(4). All data are quarterly and collected from the *Monthly Reports of the Deutsche Bundesbank* (M3, and the interest rates used in section 3), and from the national accounting provided by the *German Institute for Economic Research (DIW)* (GNP, and its 1991 implicit deflator). We use seasonally *unadjusted* data because, as Friedman (1983) already emphasized, using seasonally adjusted money growth rates can seriously bias volatility estimates downwards. On the other hand, to avoid an exaggerated volatility in the aftermath of the monetary union, we adjust the annual money growth rates in 1990(3) – 1991(2).

Testing for Granger–causality requires stationary variables. Therefore, we applied the augmented Dickey-Fuller procedure to test for the presence of unit roots in the volatility and velocity series.[3] We used the AIC information criterion to select the lag–orders p, q in the test equation (1).[4] Based on this specification, money growth volatility Granger–causes income velocity if the

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[2]Note that $Var(\Delta_4 m_t) = Var(\sum_{i=0}^{3} \Delta m_{t-i})$. Thus, the standard deviations of annual and quarterly rates differ mainly due to the serial correlation of quarterly rates.

[3]Results of unit root tests are not presented but are available on request. Note that the stationarity of volatility is implied by the stationarity of money growth. The tests clearly indicate that both variables appearing in equation (1), the growth rates of income velocity and the volatility of annual M3 growth, are stationary. All regressions were performed using *Eviews 2.0*.

[4]The presented results do not depend on the information criterion chosen. For example, applying the Schwartz–criterion, which generally selects smaller models than AIC, would lead to the same conclusions. For a detailed discussion of different model–selection and information criteria, see e.g. Lütkepohl (1991).

Figure 1:

Growth Rates and Conventional Volatility Measures of German M3

Notes: Volatility is calculated as the moving two–year standard deviation of money growth rates which are adjusted for the shift due to the German monetary union in 1990. The impact of this outlier would last about three [two] years for annual [quarterly] rates.

estimated volatility coefficients, i.e. the $\hat{\beta}$s, are jointly significant. Moreover, we examine whether volatility has a significant *long–run* effect on velocity, i.e. we test the coefficient restriction

$$\frac{\sum_{j=1}^{q} \beta_j}{1 - \sum_{i=1}^{p} \alpha_i} = 0.$$

According to Friedman's hypothesis this constraint should be rejected. Instead, the expression should be negative because the hypothesis is that an increase in the volatility of monetary expansion causes income velocity to *fall*.

The results of the Granger–tests support the volatility hypothesis for the unified Germany, see Table 1. Since non–causality is rejected at the 5%

Table 1:

Granger–Causality Tests
for the M3–Volatility/Velocity Linkage

Sample	(p,q)	$\hat{F}$; $[H_0 : \beta_j = 0 \quad \forall j]$	$\sum \hat{\beta}_j / (1 - \sum \hat{\alpha}_i)$
76(1) – 95(4)	(4,1)	4.04**	−1.21*

Notes: Notation is based on equation (1). $\hat{F}$ tests the null–hypothesis that all βs in (1) are jointly zero, i.e. that money growth volatility does not Granger–cause changes in income velocity. *, and ** denote significance at the 10%, and 5% level, respectively.

level and the long–run effect of money growth volatility is negative, increased monetary volatility lowers income velocity. Thus, the Granger–test confirms the findings of Thornton (1995) who, however, considered *M1* and did not discuss the sign of the long–run effect.

Yet this evidence for Friedman's volatility hypothesis should be viewed with caution. First, since the growth rate of velocity is the *difference* be-

Figure 2: M3 Income Velocity in Logarithms

Notes: Velocity is calculated as the ratio between nominal GNP and M3, where both series are adjusted for the unification–shift in 1990(3).

tween the growth rates of GNP and money supply, a velocity decline does not necessarily reflect an increase in the demand for money. And secondly, changes in velocity may be caused by a number of factors acting simultaneously. Therefore, bivariate causality tests may be subject to specification bias due to omitted variables, see Lütkepohl (1982).

As a consequence, Katsimbris and Miller (1993) performed Granger–causality tests including additional variables. However, as Zellner (1979) already emphasized, causation should be established in the context of a confirmed subject matter theory. Since Friedman's volatility hypothesis centers around the behavior of the demand for money, it is reasonable to investigate the impact of money growth volatility within the context of a money demand function.

3 Volatility and the Demand for Money

In this section, we reexamine Friedman's volatility hypothesis within the more general and theory–guided framework of a money demand function, thus accounting for the misspecification problem due to omitted variables. Moreover, a "volatility–augmented" money demand function should reveal whether increased money growth volatility actually *increases* money demand. To that aim, we specify a demand function for real M3 and test for the significance of money growth volatility included as additional regressor.

We consider a demand function for the log of real M3, $m - p$, including the log of real GNP, y, as the scale variable, and the growth rate of the implicit GNP deflator, Δp, as well as a weighted interest rate component, r, both capturing the opportunity costs of holding money. The interest rate component r is defined as the difference between the typical German long–term interest rate (*Umlaufsrendite*) and a weighted sum of short–term interest rates pertaining to the interest–bearing elements of M3.[5] The shifts in the levels and the seasonal pattern of the money and income series in 1990(3) are captured by a "unification–dummy" D_t, where $D_t = 1$ for $t \geq$ 1990(3) and zero otherwise.

Since $m - p$, y, and the inflation rate Δp are nonstationary, a cointegrating relation between these variables can be interpreted as a *long–run* money demand function.[6] The *short–run* dynamics of money demand, on the other

[5]The weights correspond to the average proportions of time deposits and saving deposits, respectively, in M3. For the pre–unification period the weight is 0.24 for time deposits and 0.42 for saving deposits, see Issing and Tödter (1995). For the post–unification period the weigths change to 0.30 for time deposits and 0.33 for saving deposits, see Wolters, Teräsvirta and Lütkepohl (1996).

[6]In accordance with Issing and Tödter (1995) and Wolters, Teräsvirta and Lütkepohl (1996) we found that the interest rate spread r is stationary. Results of the unit root tests

hand, have to be specified using an error correction model, see Engle and Granger (1987). In the subsequent analysis we follow e.g. Hansen and Kim (1995) and Wolters, Teräsvirta and Lütkepohl (1996) and focus on a conditional single equation model for money demand. In this framework, the long–run and the short–run components can be estimated simultaneously, see Stock (1987) and Banerjee, Dolado, and Mestre (1994).

Applying a general–to–specific procedure, we obtain the following dynamic specification for the real money demand function:

$$\begin{aligned}\Delta(m-p)_t = \underset{(6.8)}{0.16} + \underset{(15.8)}{0.14}\Delta D_t + \underset{(2.1)}{0.01} D_t + \underset{(1.7)}{0.10}\Delta(m-p)_{t-1} \\ - \underset{(3.0)}{0.19}\Delta y_{t-1} - \underset{(4.1)}{0.56} r_{t-1} - \underset{(4.9)}{0.93}\Delta^2 p_{t-1} \\ - \underset{(4.0)}{0.10}\left[m_{t-1} - p_{t-1} - y_{t-1} + \underset{(3.2)}{9.30}\Delta p_{t-1}\right] \qquad (2)\end{aligned}$$

$\bar{R}^2 = 0.90 \qquad Q(16) = 11.93\ [0.78] \qquad ARCH(2) = 1.61\ [0.21]$

Notes: t-values in parantheses, and p–values in brackets. The regression additionally included seasonal dummies. $ARCH(2)$ tests against second order ARCH–effects and $Q(16)$ denotes the Ljung–Box statistic against serial correlation.

The cointegration relation in question, i.e. the error correction term, appears in the square brackets. Note that we could not reject the null hypothesis that the long–run income elasticity of money demand is one. A significantly negative coefficient of the error correction term indicates cointegration. Using the critical values for the estimated t–statistic given in Banerjee, Dolado, and Mestre (1994, Table 4) we find cointegration at the 5% level. All in all, equation (2) leads to a plausible specification of the long–run money demand and its short–run dynamics. Therefore this specification will be used as a starting point for the analysis of the impact of money growth volatility on money demand.

are not presented but are available on request.

3.1 Money demand and the standard deviation of money growth

Next, referring to the error correction equation (2), we investigate the significance of money growth volatility for the demand for money. Varying the lag length for money growth volatility from one to eight we apply the AIC information criterion to determine the appropriate lag order. The resulting specification contains only the first lag of volatility:

$$
\begin{aligned}
\Delta(m-p)_t = \underset{(7.2)}{0.18} + \underset{(15.3)}{0.14}\Delta D_t + \underset{(2.9)}{0.01}D_t + \underset{(1.2)}{0.07}\Delta(m-p)_{t-1} \\
- \underset{(3.2)}{0.20}\Delta y_{t-1} - \underset{(4.4)}{0.58}r_{t-1} - \underset{(5.4)}{1.04}\Delta^2 p_t \\
- \underset{(4.6)}{0.12}\left[m_{t-1} - p_{t-1} - y_{t-1} - \underset{(3.8)}{9.75}\Delta p_{t-1}\right] - \underset{(2.1)}{0.26}S_{t-1}
\end{aligned}
\tag{3}
$$

$\bar{R}^2 = 0.90 \qquad Q(16) = 11.22\ [0.68] \qquad ARCH(2) = 1.51\ [0.23]$

Note: S_t denotes money growth volatility approximated as the two–year standard deviation of annual M3 growth rates. For further explanations see equation (2).

In view of the increased monetary volatility in the aftermath of the German unification the impact of volatility on money demand may have changed. However, additional regressors, $D_t \cdot S_{t-k}$, included in the specification to capture this possible structural break, proved to be insignificant.

Comparing the volatility–augmented money demand (3) with its point of reference, i.e. equation (2), shows that the estimated coefficients remained essentially unchanged. Hence, including the volatility proxy S_t does not induce multi–collinearity, which suggests that money growth volatility actually provides new information about the demand for money.

However, contrasting Friedman's volatility hypothesis, the negative sign of the estimated volatility coefficient implies that an increase in money growth volatility *decreases* the demand for money. This influence of volatility is *statistically* significant as well as *economically* relevant. Since the German monetary union, money growth volatility has increased by more than four percentage points, see Figure 1. According to equation (3) this contributes to decreasing the demand for money by more than one percentage point.

To what extent does this result depend on the *ad hoc* definition of monetary variability as a moving standard deviation of money growth rates? In the following, we address this question considering a more data– and theory–oriented money growth volatility measure.

3.2 Money demand and the expected volatility of money growth

The degree of volatility approximated as a moving standard deviation of money growth obviously depends on the number of observations the standard deviation is based on. Following former empirical studies we so far calculated volatility "remembering" the last two years but, of course, this choice is arbitrary. In particular, modelling people's "memory" in this *ad hoc* way completely neglects the structure of the data generating process. In the following, we therefore *estimate* an alternative volatility measure, namely the *conditional* standard deviation of nominal money growth which can be interpreted as its expected volatility. This should be a more convincing proxy for perceived uncertainty than the conventional standard deviation used before.

To begin with we identified and estimated a univariate forecast equation for quarterly money growth rates. Applying a general–to–specific approach, the estimated model is given by:

$$\Delta m_t = \underset{(2.6)}{0.01} + \underset{(2.7)}{0.26}\Delta m_{t-4} - \underset{(2.7)}{0.19}\Delta m_{t-5} - \underset{(2.2)}{0.16}\Delta m_{t-6}$$
$$-\underset{(2.5)}{0.18}\Delta m_{t-7} + \underset{(5.0)}{0.49}\Delta m_{t-8} + \hat{\varepsilon}_t \qquad (4)$$

$\bar{R}^2 = 0.89 \qquad Q(12) = 15.03\ [0.24] \qquad ARCH(4) = 14.62\ [0.0006]$

Ljung–Box statistics computed from the residuals indicate that equation (4) adequately accounts for the serial correlation in money growth rates. The test–statistic $ARCH(4)$ against conditional heteroskedasticity, however, provides strong evidence for fourth–order ARCH effects in the residuals.

The ARCH model has been applied to model the volatility of many economic time series.[7] In our context, the ARCH model characterizes the distribution of the stochastic forecast error ε_t of money growth conditional on past information Θ_{t-1} which includes the realized values of money growth rates, i.e.

$$\Theta_{t-1} = \{\Delta m_{t-1}, \Delta m_{t-2}, ...\}.$$

Specifically, Engle's (1982) original ARCH model assumes that the forecast errors ε_t are conditionally normal, i.e.

$$\varepsilon_t | \Theta_{t-1} \sim N(0, \sigma_t^2) \qquad (5)$$

where

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 \qquad (6)$$

with $\alpha_0 > 0$ and $\alpha_i \geq 0$, $i = 1, \ldots, q$, to ensure that the conditional variance σ_t^2 is positiv. Therefore, $\hat{\sigma}_t$ is the expected volatility of money growth in period t given the information available in $t-1$.

The distinguishing feature of ARCH models is not simply that the conditional variance σ_t^2 is a function of past information, but rather the particular

[7] See e.g. Bera and Higgins (1993) and Bollerslev et al. (1992) for comprehensive surveys of ARCH models and its applications.

functional form that is specified. In the ARCH model, the variance of the current error ε_t, conditional on the realized values of the lagged errors, is an increasing function of the magnitude of the lagged errors, irrespective of their signs. Hence, large errors of either sign tend to be followed by a large error of either sign. This captures the phenomenon that episodes of high volatility are generally described as the clustering of large shocks.[8] The order of the lag q in (6) determines how long a shock persists in conditioning the variance of subsequent errors.

Figure 3: Expected Volatility of German M3 Growth

Notes: The conditional standard deviation $\hat{\sigma}_t$ of quarterly money growth rates is based on (4) and (7). $\hat{\sigma}_t^a$ denotes the conditional standard deviation of money growth referring to a forecast equation for *annual* rates. (This forecast equation is not presented but is available on request.) Money growth rates are adjusted for the unification–shift in 1990(3).

Since ARCH effects of higher order were not significant, we specified

[8]We additionally experimented with threshold (TARCH) and exponential (EGARCH) ARCH models which allow for asymmetry in the conditional variance, see Bera and Higgins (1993). However, these more flexible models were not supported by the data.

the residuals of regression (4) as an ARCH(4) process. This leads to the following equation for the conditional variance of money growth:

$$\hat{\sigma}_t{}^2 = \underset{(2.1)}{4.95} \cdot 10^{-5} + \underset{(2.5)}{0.26}\hat{\varepsilon}_{t-3} + \underset{(2.7)}{0.29}\hat{\varepsilon}_{t-4} \tag{7}$$

The resulting estimate $\hat{\sigma}_t$ for the expected volatility of money growth is displayed in Figure 3. Similar to the conventional volatility measure S_t, the expected volatility of money growth, $\hat{\sigma}_t$, sharply increases in the 1990s. However, in comparison with Figure 1, Figure 3 suggests that the standard deviation S_t tends to exaggerate the actual monetary volatility, in particular since 1993.

Of course, an alternative estimate of expected money growth volatility can be derived using a forecast equation for *annual* rather than quarterly growth rates. However, as opposed to the conventional standard deviations displayed in Figure 1, Figure 3 illustrates that the difference between the estimated *conditional* standard deviations $\hat{\sigma}_t$ and $\hat{\sigma}_t^a$ is rather small. Thus, applying the ARCH model is not only more convincing from a theoretical point of view. It also avoids the ambiguity stirred by the choice of a particular *ad hoc* volatility measure.

Referring again to the money demand function (3), we can now test for the significance of perceived uncertainty about monetary expansion proxied by the expected volatility $\hat{\sigma}_t$. The corresponding volatility–augmented money demand function (8) confirms the results based on equation (3). In particular, the estimated volatility coefficient is significantly negative implying that increased money growth volatility decreases, not increases, the demand for money in Germany:

$$\begin{aligned}
\Delta(m-p)_t = & \underset{(6.8)}{0.17} + \underset{(15.0)}{0.14}\Delta D_t + \underset{(2.8)}{0.01} D_t + \underset{(1.4)}{0.08}\Delta(m-p)_{t-1} \\
& - \underset{(2.7)}{0.17}\Delta y_{t-1} - \underset{(4.1)}{0.57} r_{t-1} - \underset{(5.1)}{1.03}\Delta^2 p_t \\
& - \underset{(3.8)}{0.11}\left[m_{t-1} - p_{t-1} - y_{t-1} - \underset{(3.3)}{9.18}\Delta p_{t-1} \right] - \underset{(2.4)}{0.87}\hat{\sigma}_t \qquad (8)
\end{aligned}$$

$\bar{R}^2 = 0.91 \qquad Q(16) = 12.75\ [0.70] \qquad ARCH(2) = 0.69\ [0.51]$

Thus, money growth volatility influences the demand for money in the unified Germany. At first sight, this evidence is in line with the causality test results presented by Thornton (1995). However, both volatility–augmented money demand functions, (3) and (8), demonstrate that Friedman's volatility hypothesis cannot serve as an explanation for this phenomenon because it predicts the counterfactual relationship.

4 Concluding Remarks

In the aftermath of the German monetary union various "disruptive influences" apparently undermine the Bundesbank's attempt to follow the monetarist proposition of a predictable growth rule of money supply. According to Friedman's volatility hypothesis stirred by the Fed's "monetarist experiment" in the early eighties, increased volatility of money growth raises the degree of perceived uncertainty and thereby increases the demand for money. However, for many countries there is only weak evidence for a volatility/velocity linkage. Yet, the findings of Thornton (1995) suggest that the case of Germany seems most favorable for Friedman's hypothesis.

This paper shows that for the unified Germany, the development of the monetary target aggregate M3 sharply contradicts Friedman's hypothesis concerning the role of money growth volatility. In the first part of the paper we followed the approach of former empirical studies and showed via Granger–tests that German M3 growth volatility causes changes in income velocity. However, bivariate causality tests are subject to specification bias due to omitted variables. Therefore, in the second part of the paper, we reexamined the role of money growth volatility within the theory–based framework of a money demand function that controls the influence of additional factors, like prices and interest rates. The examination of volatility–augmented money demand functions revealed that — in contrast to Friedman's hypothesis — increased money growth volatility *decreased*, not increased, the demand for money.

We demonstrated the robustness of this result considering the impact of an alternative volatility measure. Specifically, we applied an ARCH model to estimate the *expected* volatility of money growth, since expected volatility seems to be a more convincing proxy for perceived uncertainty than the conventional standard deviation used so far. Moreover, this approach avoided the ambiguity due to the choice of a particular *ad hoc* volatility measure.

The increased volatility of German money growth has stirred up the debate about adopting a monetary aggregate as the intermediate target of monetary policy. In view of the coming European monetary union, there is a controversy whether monetary targeting will be an appropriate policy design for the future European central bank. Although this paper clearly rejects Friedman's volatility hypothesis, it yet confirms the impact of monetary variability for the German monetary transmission mechanism. At least this points to the significance of a credible monetary policy stance geared to the stabilization of expectations.

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